

REMARKS

Claims 98-106 and 119-130 are pending in the application. A second Terminal Disclaimer is enclosed to overcome the double patenting rejections over U.S. Patent Application Nos. 09/536,251; 09/837,722; and 09/621,028.

Related application Serial Nos. 09/836,059 and 09/836,080 have been abandoned.

All of the claims now include contacting or spraying a semiconductor article or workpiece with a heated aqueous solution in combination with use of ozone, as described at pages 12-14 of the application. The claims are not directed to immersion. None of the cited references, alone or in combination, suggest contacting or spraying a semiconductor article with a heated solution while exposing the article to ozone. As explained at pages 1-4 of the application, the liquid bath cleaning techniques currently used in the semiconductor manufacturing industry require a relatively large number of steps, using a relatively large number of chemicals. As a result, they are time-consuming and they slow the manufacturing process. Additionally, the equipment required to perform these liquid bath techniques is bulky, as various tanks are needed, and the fabrication facility must therefore provide space for the tanks. This adds to the overall processing costs. Moreover, the spent chemicals from such facilities must be appropriately disposed of in an environmentally acceptable way, further increasing the costs for cleaning semiconductor articles. It does not appear that any of the immersion prior art references discussed above have overcome these disadvantages.

Regarding the rejections at paragraph 2 of the June 4, 2002, Office Action, Applicant submits that the specification adequately teaches "rotating the semiconductor article in a gas or air environment," even though that precise language is not used in the specification. (See page 14.) Initially, the specification discusses spraying the heated liquid onto the wafer. Inherently,

this requires an air or gas environment around the wafer, because the liquid cannot be sprayed through another liquid or a solid environment around the wafer. The specification also describes use of feed and reagent gases. Again, this description only makes sense if the wafer is in an air or gas environment. While the specification also makes mention of immersion, the claims are not directed to immersion methods. Notwithstanding, the objected to language has been deleted from the claims.

The claimed steps of use of ozone and heated liquid embody an important aspect not recognized in the prior art. As described in Example 1, ozone is introduced into the process chamber along with heated liquid (at 90C in this example). Page 29, lines 10-23. A concentration of ozone is created in the chamber, e.g., by release of bubbles of ozone gas in the liquid; by ozone gas coming out of solution in the liquid; or by direct injection or spray of ozone into the chamber. Since the solubility of ozone (like many gases) is inversely proportional to temperature, very little ozone can be dissolved into the heated liquid. (Indeed, many prior art processes using ozone rely on room temperature or chilled liquid—to increase the ozone concentration in the liquid). Unfortunately, the reaction kinetics (or chemical cleaning action of the ozone) at room temperature or below is slower in comparison to the reaction kinetics at higher temperatures. Thus, for cleaning with ozone, on the one hand, low liquid temperatures are desired to allow for higher dissolved ozone concentrations. However, on the other hand, higher liquid temperatures are desired, to increase the reaction kinetics, and thereby reduce process times. The claimed methods harmonize these two competing parameters, as follows.

The wafer is spinning. This causes the heated liquid to form a boundary layer on the wafer. Since the liquid sprayed onto the wafer is heated, the amount of dissolved ozone in the liquid is low. However, because the liquid is in a thin layer, and because ozone is provided into

the chamber, the ozone is able to diffuse through the liquid layer at a high rate, to react at the wafer surface. Since diffusion of ozone through the thin liquid layer is the primary reaction mechanism ( as opposed to dissolution of ozone in the liquid), the advantages of using heated liquid (faster reaction times) are achieved, without the disadvantages (low dissolved concentrations of ozone and slower reaction times).

Turning to the rejections at paragraphs 8 and 9 of the Office Action, with respect to the claimed heated solution and ozone elements, all the prior art cited falls into either the immersion tank processing category or the spin processing category. Otsuka JP H03-208900 and Wada JP 62-117330 are in the immersion category. Specifically, Otsuka et al. and Wada et al. teach bubbling an oxidizing gas onto a wafer immersed in a liquid bath. Otsuka describes immersion in a solution having a maximum temperature of 80°C, optionally including ozone gas bubbles (Translation p. 9). Wada et al. describes a cleaning liquid bath at up to 140° C, with ozone bubbling up to an immersed wafer. Matsuoka (EP 548596) teaches away from heating: “Heating the substrates does not permit wet ozone to have well-enough effects, because any thin water film cannot occur even when a wet ozone-containing gas is fed.” Page 3, lines 32-35. In example 1 of EP 596, the water temperature is 25° C. Page 5, line 55. In comparative Example 1, the water is at 20° C. Page 6, line 12. Consequently, Matsuoka EP 596 if anything suggests use of liquid only at room temperature. Hence, there is no motivation to combine Matsuoka EP 596 with a reference that teaches heating.

As noted by the Examiner, Ohmi et al. (apparently the fourth reference applied against the claims at paragraph 8 of the Office Action) also does not teach use of a heated liquid.

Regarding the rejections at paragraph 9 of the Office Action, Fukazawa et al. teaches placing a wafer into a cleaning vessel that is filled with overflowing deionized water (abstract; col. 2, lines 42-45). Fukazawa and Kajita are both silent on temperature.


Turning to the rejections at paragraph 11 of the Office Action, Lampert describes forming a mist using water at 10-90° C (Col. 7, line 11) and then forming liquid phase chemicals by reacting gas phase chemicals with the water mist. The mist is not an aqueous solution as claimed. Rather, it is a low volume aerosol having inadequate heat capacity needed for heating the workpieces. The mist of pure water interacts with a gas to form a chemically active substance, which removes contaminating particles from the wafer (col. 2, lines 52-55; col. 4, lines 59-64). In Lampert et al., the use of a mist, or finely divided water, is apparently essential, to allow the gas to react with the water (col. 2, lines 52-55). The use of such a mist or fog makes effective processing difficult or impossible to achieve because the mist cannot be made uniform throughout the chamber (see, e.g., Ohmi et al., Col. 4, lines 60-63). Lampert, in essence, is a form of the 4-Chem or RCA clean described at pages 1-3 of the specification, but using gases for chemical generation, instead of liquids. Schellenberger et al. teaches immersion and is silent on temperature, as is Ohmi.

In view of the foregoing, it is submitted that the claims are in condition for allowance, and a Notice of Allowance is requested.

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**Claim Sheet Marked Up To Show Changes**

98. (Twice Amended) A method for cleaning a semiconductor wafer[s] comprising:
- (a) rotating a wafer in a processing chamber;
  - (b) contacting a surface of the wafer with a heated aqueous solution and simultaneously [contacting the wafer with] providing ozone into the processing chamber in an amount sufficient to create an oxidizing effect on the surface of the wafer to oxidize contaminants thereon; and
  - (c) [rinsing the surface of the wafer to remove] removing oxidized contaminants from the surface thereof.
99. A method as defined in claim 98 wherein the aqueous solution is water.
100. A method as defined in claim 98 wherein the aqueous solution contains an acid.
101. A method as defined in claim 98 wherein the aqueous solution is sprayed onto the surface of the wafer to form a thin aqueous film thereon.
102. A method as defined in claim 98 wherein the aqueous solution is adjusted to a temperature sufficient to effect oxidation on the surface of the wafer.
103. (Amended) A method as defined in claim [102 wherein the temperature of the solution is less than 200°C] 98 wherein the contaminants are removed by rinsing.

104. A method as defined in claim 98 wherein the ozone is injected into the processing chamber.

105. A method as defined in claim 98 wherein the ozone is admixed with a carrier gas.

106. A method as defined in claim 105 wherein the carrier gas is selected from the group consisting of oxygen, nitrogen, air and inert gas.

119. The method of claim [118] 98 wherein the ozone is provided as a gas around the semiconductor [article] wafer.

120. The method of claim [118] 98 wherein the ozone is provided in an ozone/liquid solution.

121. The method of claim [120] 98 wherein the ozone/liquid solution is supplied separately from the heated aqueous solution.

122. (New) A method for cleaning organic material from a surface of a workpiece comprising:

(a) spraying a heated aqueous solution onto the surface of the workpiece and simultaneously contacting the surface with ozone to effect oxidation of the organic materials on the surface of the workpiece to oxidize the contaminants; and

(b) removing oxidized contaminants from the surface.

123. (New) The method of claim 122 wherein the aqueous solution comprises water.
124. (New) The method of claim 122 wherein the aqueous solution comprises an acid.
125. (New) The method of claim 122 wherein the aqueous solution forms a thin aqueous film on the surface of the workpiece.
126. (New) The method of claim 122 wherein the organic material comprises a coating of photoresist.
127. (New) A method for cleaning an organic coating off of a surface of a semiconductor article comprising:
- placing the article into a processing chamber;
  - spraying the surface of the article with a heated aqueous solution, while simultaneously contacting the surface of the article with ozone in an amount sufficient to oxidize the organic coating;
  - removing the oxidized organic coating from the surface of the article; and
  - removing the article from the processing chamber without performing a separate rinsing step.
128. (New) The method of claim 127 further including the step of rotating the article.
129. (New) The method of claim 127 wherein the aqueous solution and the ozone are sprayed onto the surface of the article in solution form.

130. (New) The method of claim 127 wherein the aqueous solution is heated to a temperature between 50° C and 90° C.